



Bridges

There are more than 500,000 bridges in the United States!

Primary Bridge Forces

Tension: a *pulling* force that acts to *lengthen* the thing it is acting on.



- If the tension becomes too large, the material will first **yield** (permanently deform) and then **snap/rupture**.
Example: springs stretched beyond their “elastic limit” permanently deform.

Compression: a *pushing* force that acts to *shorten* the thing that it is acting on.



- If the compression becomes too large, the material may **buckle**.

Example: 2-meter stick pushed against wall

- In which direction does buckling occur? In the direction that the material is the **thinnest**.
- Length: Compare 1-meter stick vs. 2-m stick.
- Conclusion: Buckling is more likely for **longer** objects and **thinner** objects.

Types of Bridges:

(1) **Beam Bridge:** a horizontal structure resting on two “piers”



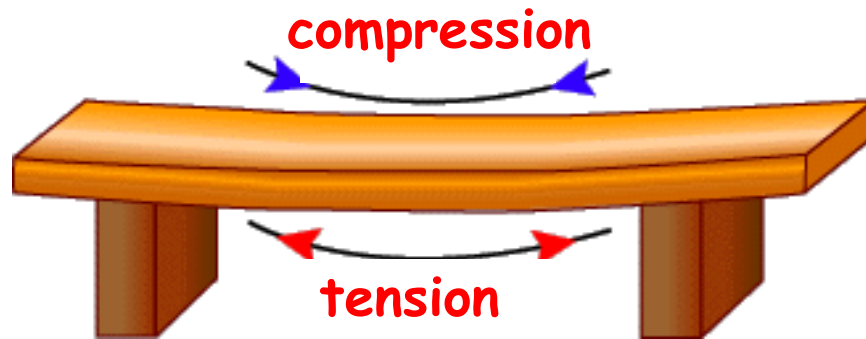
- the simplest and least expensive bridge
- Can span a distance of up to 200 feet
- If the needed span is more than 200 feet, additional piers are required (could become a disruption to river traffic)



Forces in a Beam Bridge

Demo: Use a sponge notched on top and bottom as a beam. When loaded with weight, the notch on top **closes** and the notch on bottom **opens**.

Conclusion:



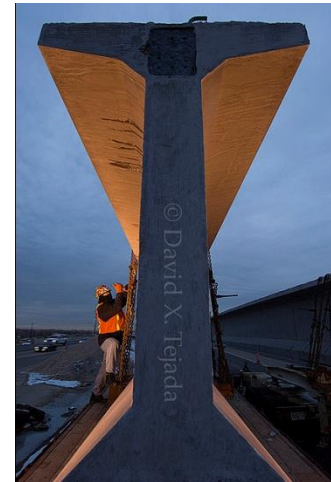
The ***top*** of a beam experiences **compression**.

The ***bottom*** of a beam experiences **tension**.

I-Beams



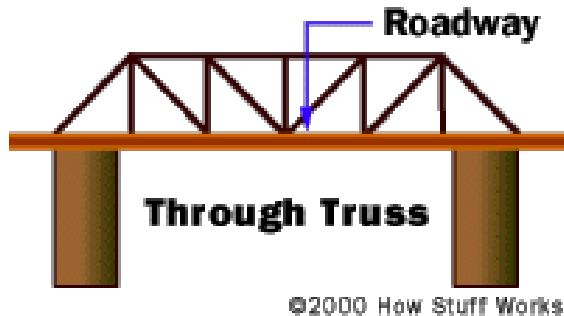
Why are many beams often made in the shape of an “I”? (appropriately called I-beams)



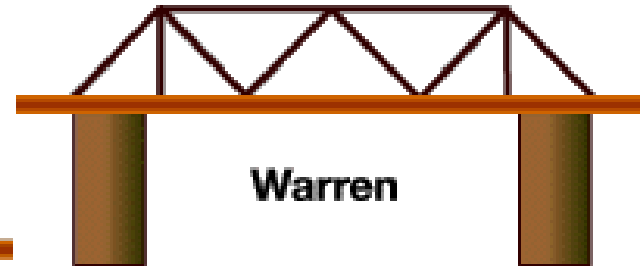
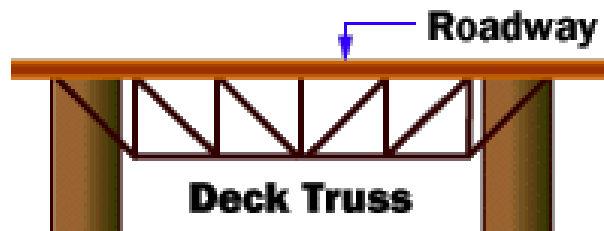
With most of the compression on top and most of the tension on bottom, the middle of the beam would experience little force! So, less material is needed there. It's more efficient than a solid beam - very strong for its weight.

Truss Bridges

To strengthen a beam bridge, a truss is often added on top or on bottom of the beam. This increases the bridge's rigidity (keeps it from deforming when loaded), and allows the forces to be dissipated (spread out over a greater area) throughout the truss. The bridge can then span a longer distance than a simple beam bridge.



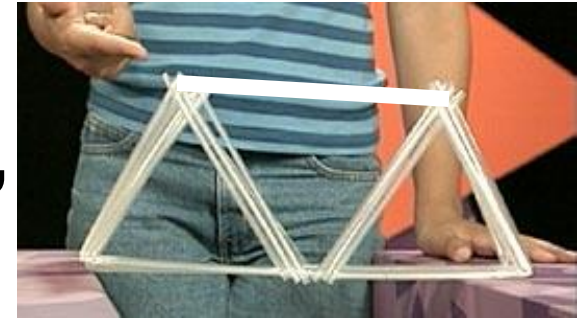
Examples



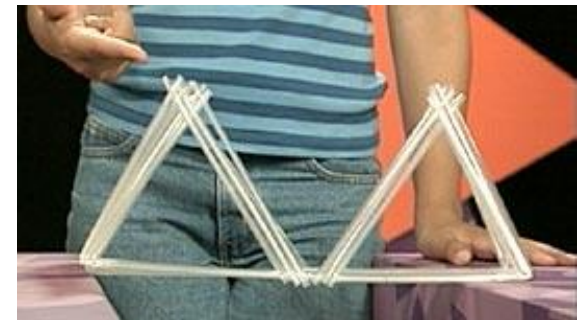
Demo: Straw Truss Bridge

Add weight to straw bridge...

- When the triangles of the truss are connected, the bridge is strong, and can support the weight.
- When the triangles are ***not*** connected, the bridge is MUCH less rigid and fails (the triangles are basically doing nothing!)



Holds!



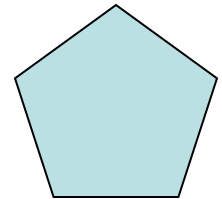
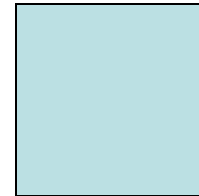
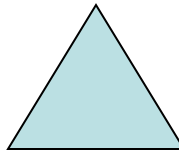
Fails!

Just like a simple beam, the top of a truss is loaded in **compression**, while the bottom is in **tension**. The other “members” in between can experience both forces.

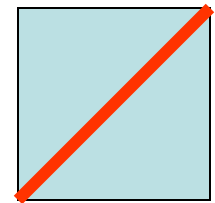
Why do trusses always consist of triangles?

They dissipate the forces more efficiently than other shapes, and are also more stable.

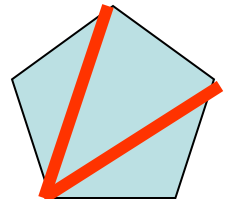
Demo: Compare...



To strengthen and stabilize the square



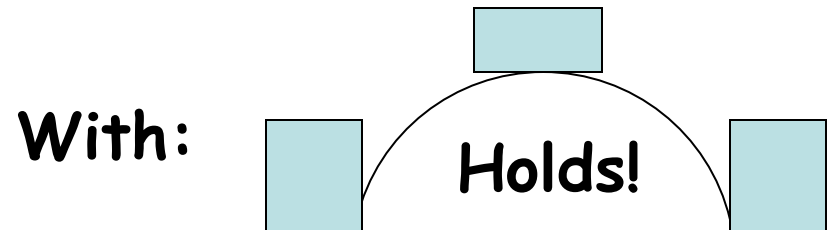
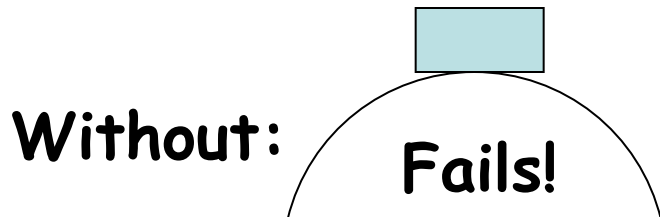
To strengthen and stabilize the pentagon



- (2) Arch Bridge:** a semi-circular structure with “abutments” (supports) on each end.
- The weight is naturally carried outward along the curve of the arch to the “abutments”.
 - The entire bridge, then, is under **compression**
 - Arch bridges can span longer distances than beam distances (up to ≈ 1000 ft)

Demos:

- Cardboard arch with and without abutments



- Small wooden arch bridge that you can stand on!

Many ancient bridges were arch bridges made out of stone.



Old arch bridge in Israel; picture taken by Penelope Rosenstock-Murav, Central Class of 2009



Concrete arch bridge overlooking the Hoover Dam



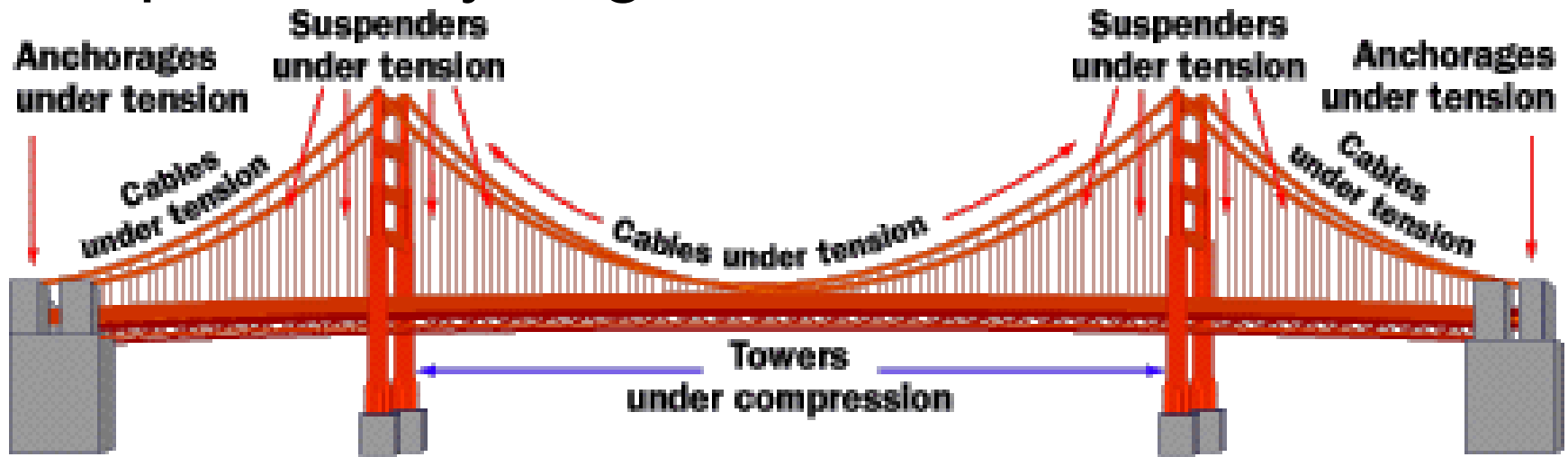
Under Construction

Some arch bridges are even made of wood...



Arch bridge in South Dakota;
picture taken in 2006.

(3) Suspension Bridge: roadway is suspended by huge cables...



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- The cables transfer the compression into the towers, which dissipate the compression directly into the earth below the towers.
- The cables transfer the tension to the anchorages, which dissipate the tension into the earth.

- Can span much greater distances, up to 7000 feet!
- More expensive, but also more “aesthetically” pleasing!

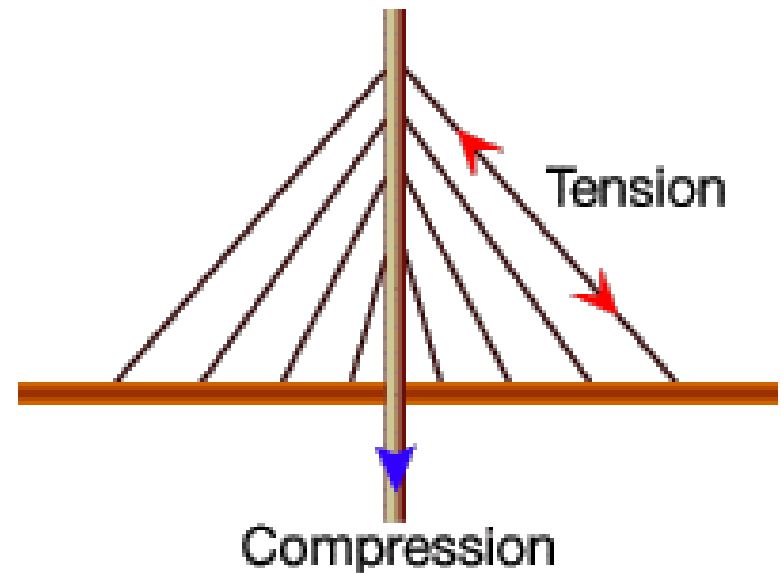


Brooklyn Bridge



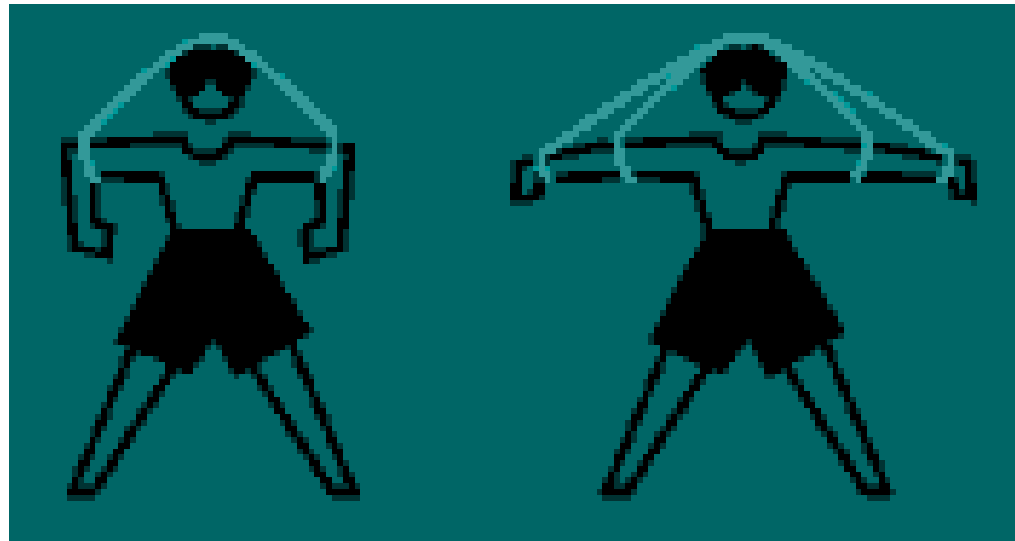
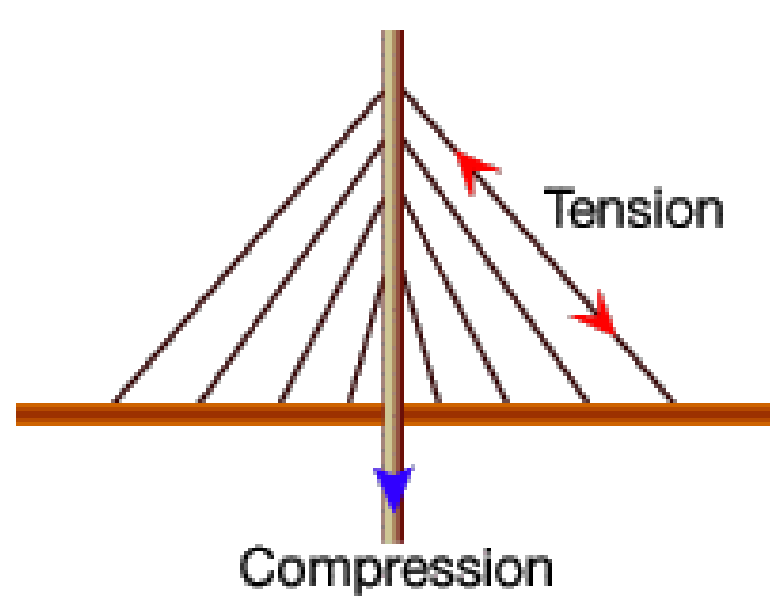
Golden Gate in
San Francisco

(4) Cable-stayed Bridge: Most modern... similar to suspension bridge, but cables are attached to roadway.
(NO anchorages at end of bridge)



Advantage: Requires less cable than suspension bridge

An analogy: The road deck in a cable-stayed bridge is supported in the same way as...



Head = Towers

Arms = Road deck

The closest cable-stayed bridge to Mansfield is found in Boston, MA. The Zakim Bunker Hill Memorial Bridge, part of The Big Dig Project in Boston, is one of the widest cable-stayed bridges in the world. The Bridge serves as the northern entrance to and exit from Boston. The Bridge is named after civil rights activist Lenny Zakim and the American colonists who fought the British in the Battle of Bunker Hill.

